Received at: 9:42PM, 2/26/2003

'03年02月27日(木)11時36分 宛先:米 OLIFF 発信: R:142 P.50

CERTIFICATE

I, Katsuji MIYASHITA, residing at 1-23-310, Minami-cho, Toda-shi, Saitama-ken, 335-0025 Japan, hereby certify that I am the translator of the attached document, namely a Certified Copy of Japanese Patent Application No. 2001-064073 and certify that the following is a true translation to the best of my knowledge and belief.

Signature of Translator

February 19, 2003
Date

[Name of Document]	Application for Patent
[Reference No.]	10084400
[Date of Filing]	March 7, 2001
[Addressee]	Commissioner of the Patent Office
[Int. Cl.]	G02F 1/133
[Inventor]	
[Address]	c/o Seiko Epson Corporation, 3-5, Owa 3-chome, Suwa-shi, Nagano-ken
[Name]	Kinya OZAWA
[Inventor]	
[Address]	c/o Seiko Epson Corporation, 3-5, Owa 3-chome, Suwa-shi, Nagano-ken
[Name]	Tsuyoshi MAEDA
[Applicant for Patent]	
[Id. No.]	000002369
[Name]	Seiko Epson Corporation
[Agent]	
[Id. No.]	100093388
[Patent Attorney]	
[Name]	Kisaburo SUZUKI
[Phone No.]	0266-52-3139
[Sub-agent]	
[Id. No.]	100095728
[Patent Attorney]	
[Name]	Masataka KAMIYANAGI
[Sub-agent]	
[Id. No.]	100107261

[Patent Attorney]

[Name] Osamu SUZAWA

[Priority Claim according to Earlier Application]

[Application No.] 2000-115207

[Application Date] April 17, 2000

[Application Fees]

[Prepayment Registration No.] 013044

[Amount of Payment] 21000

[List of Documents Attached]

[Name of Document] Specification 1

[Name of Document] Drawings 1

[Name of Document] Abstract 1

[No. of General Power of Attorney] 9711684

[Proof] Required

[Name of Document] SPECIFICATION

[Title of the Invention] LIQUID CRYSTAL DEVICE, PROJECTION TYPE DISPLAY APPARATUS, AND ELECTRONIC APPARATUS

[Claims]

[Claim 1] A liquid crystal device comprising: liquid crystal; a pair of substrates having alignment films on surfaces thereof, the surfaces opposing each other with the liquid crystal provide therebetween; a plurality of scanning lines; a plurality of data lines; and a switching element and a pixel electrode provided in each of pixel areas defined by the scanning lines and the data lines, wherein a pretilt angle with respect to each of the alignment films is in the range of from 20° to 30°.

[Claim 2] A liquid crystal device according to Claim 1, wherein the alignment films each comprise one of silicon oxide and silicon nitride.

[Claim 3] A liquid crystal device according to Claim 2, wherein, when the thickness of a layer of the liquid crystal held between the pair of substrates is represented by d and the space between the pixel electrodes is represented by L, $d/L \le 1$ is held.

[Claim 4] A liquid crystal device according to one of Claims 1 to 3, wherein the pixel electrode is a light-reflecting metal electrode.

[Claim 5] A projection type display apparatus comprising a liquid crystal device according to one of Claims 1 to 4.

[Claim 6] A projection type display apparatus comprising: a light source, a light modulating device for modulating light emitted from the light source; and a projection lens for projecting the light modulated

by the light modulating device; wherein a liquid crystal device according to one of Claims 1 to 5 is used as the light modulating device.

[Claim 7] A projection type display apparatus comprising: a light source; a light modulating device for modulating light emitted from the light source; and a projection lens for projecting the light modulated by the light modulating device; wherein a liquid crystal device according to one of Claims 1 to 5 is used for a blue display portion as the light modulating device.

[Claim 8] An electronic apparatus comprising a liquid crystal device according to one of Claims 1 to 4.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to liquid crystal devices in which a pretilt angle with respect to an alignment film and the relationship of a space between pixel electrodes to a thickness of a liquid crystal layer are specifically defined, and to projection type display apparatuses and electronic apparatuses, both of which use the above liquid crystal devices. The present invention particularly relates to a technique for suppressing the generation of display defects caused by disclination lines.

[0002]

[Description of the Related Art]

Hitherto, liquid crystal display devices have been increasingly in demand for use in projection type display apparatuses, such as a

projection television, in addition to direct-view-type display apparatuses. However, in the case in which liquid crystal display devices are used for projection type display apparatuses, when the magnifying power is increased while the number of pixels is not changed from that in the past, the coarseness of a screen becomes observable. Accordingly, in order to obtain fine images even when the magnifying power is high, the number of pixels must be increased.

[0003]

[Problems to be Solved by the Invention]

However, when the number of pixels is increased while the area of the liquid crystal display device is maintained constant, in particular, in the case of an active matrix liquid crystal display device, since the areas of wire portions and switching element portions other than those of the pixels are relatively increased, the area of a black matrix covering the portions mentioned above is increased.

[0004]

In addition, in the case described above, a problem may arise in that since the distance between pixels, i.e., the space between the pixel electrodes, is inevitably decreased, when attention is given to one pixel electrode, disclination (rotation and inclination of liquid crystal molecules) is likely to occur due to the influence of electric fields from the peripheral portions of other adjacent pixel electrodes. When the disclination occurs, in addition to the wire portions and switching element portions, it becomes necessary that the areas at which it occurs be covered with the black matrix.

[0005]

As described above, when the number of pixels is increased while the area of the liquid crystal display device is maintained constant, in addition to the areas of the wire portions and the switching element portions, the areas at which the disclination occurs must be covered with the black matrix, and hence the area of the black matrix is extremely increased with respect to the display area. Accordingly, in the case described above, areas of aperture portions of the pixels, which contribute to image display, are decreased, that is, the aperture ratio is decreased, resulting in a darkened display screen. Hence, a problem may arise in that the image quality is degraded.

[0006]

Next, the display defects caused by disclination will be described in detail. A liquid crystal display device having a highly fine structure for use in a current projection type display apparatus is provided with a plurality of rectangular pixel electrodes arranged in a matrix each having a fine width of approximately 20×10^{-6} m (20 μm) square. In addition, in the highly fine liquid crystal display device, when a reflective structure is employed, the pixel electrodes are arranged with substantially no spaces therebetween on an insulating film which covers the switching elements formed on a substrate. Accordingly, in a liquid crystal display device having the reflective structure, it becomes possible that the space between the pixel electrodes can be decreased to only approximately 1×10^{-6} m (1 μm).

[0007]

In the liquid crystal display device described above having the decreased spaces between the pixel electrodes, as shown in Fig. 11, a space L between pixel electrodes 100 and 101 provided for one substrate side is approximately 1×10^{-6} m, and a distance d between a common electrode 102 provided for a substrate opposing said one substrate mentioned above and the pixel electrodes 100 and 101 is 2×10^{-6} to 4×10^{-6} m. As a result, a strong lateral electric field is applied to liquid crystal present in the boundary portion between the pixel electrodes 100 and 101. For example, in the case in which the common electrode 102 is fixed at zero voltage by grounding, +5 volts is applied to the pixel electrode 100, and -5 volts is applied to the pixel electrode 101 so as to control the alignment of the liquid crystal, when liquid crystal is used which stands with respect to the substrate upon application of a voltage, as shown in Fig. 12, a lateral electric field having +10 volts, that is, the potential difference between +5 and -5 volts, is generated in liquid crystal in an area corresponding to the pixel electrode 100 and close to the pixel electrode 101, and hence, the liquid crystal influenced by this lateral electric field has a high probability of being aligned in the direction different from that in which the liquid crystal is naturally aligned. That is, in liquid crystal in an area at which the alignment thereof is to be controlled by the pixel electrode 100, some liquid crystal molecules are aligned in a direction slightly different from that of the other liquid crystal molecules. As a result, a linear display defect, a so-called disclination line, is generated in a boundary area (area along a

boundary line indicated by reference mark DR in Fig. 12) of the liquid crystal in which the alignment direction is slightly different. When the width of this linear display defect was actually measured, it was found that the width thereof was approximately 3×10^{-6} m (μm) on the average.

[0008]

Fig. 14 is a view showing the lightness of a pixel portion of a conventional liquid crystal display device, obtained by computing a light reflection state of the pixel portion. As shown in this figure, it is understood that due to the generation of disclination lines, the luminance in the pixel is decreased at the two sides thereof.

[0009]

In order to reduce the display defects caused by disclination as small as possible, a frame inversion driving method is employed, which is capable of making as many adjacent pixel electrodes as possible have the same polarity, so that the liquid crystal is driven by applying voltages having the same polarity to all pixel electrodes in each frame when display is performed. However, the frame inversion driving method has not been able to totally solve the problem described ... That is, when white or black display is performed over the entire display area, the frame inversion driving works effectively, but in a display mode in which white display and black display are both present in the display area, the boundary portion of the white and the black display become nearly gray display, and the display at the boundary portion is put in a blurred state. For example, as shown in Fig. 13, in the case in which a

letter "A" is displayed in black on a background displayed in white, a gray display area is generated by disclination lines in the white display portion around the outline of the "A" displayed in black, and the outline of the letter "A" becomes blurred, resulting in a display mode having low contrast. In particular, in a projection type display apparatus, the situation becomes more serious due to a magnifying projection display system.

[0010]

As a liquid crystal driving method, in addition to the frame inversion driving method, there may be mentioned, for example, a line inversion driving method in which the polarity of a driving voltage applied to each longitudinal line or to each lateral line is different from that applied to the line adjacent thereto, or a dot inversion driving method in which the polarity of a driving voltage applied to each pixel electrode is different from that applied to the pixel electrodes adjacent thereto, and since the individual driving methods have their own advantages, it is preferable that various driving method be selected for projector type liquid crystal panels. However, due to the disadvantageous generation of disclination lines described above, an unfavorable situation exists in that the line inversion driving method or the dot inversion driving method, in which the difference in potential between the pixel electrodes adjacent to each other is increased, cannot be employed as a driving method for a highly fine liquid crystal panel.

[0011]

In addition, among characteristics required for projectors, the first required one is currently the lightness, and when microlenses are provided at positions corresponding to the pixels so as to converge light at the aperture areas, an effective aperture ratio can be improved. However, when the microlenses are provided, light flux density incident on the pixel is increased, and hence it is pointed out that since an alignment film is damaged, abnormal alignment of the liquid crystal may occur in some cases. Heretofore, for ease of description of the present invention, color filters and polarizers, which are generally provided in the liquid crystal display device, are not described, and the aperture ratio of the panel itself has been primarily described as the subject.

[0012]

The present invention was made in consideration of the situations described above. An object of the present invention is to provide a liquid crystal device, a projection type display apparatus, and an electronic apparatus. The liquid crystal device is capable of performing bright display, in which the generation of display defects caused by abnormal alignment of the liquid crystal is suppressed by defining the pretilt angle with respect to the alignment film and the specific relationship of the space between the pixel electrodes to the thickness of the liquid crystal layer.

[0013]

[Means for Solving the Problems]

To these ends, a liquid crystal device of the present invention comprises liquid crystal; a pair of substrates having alignment films on

surfaces thereof, the surfaces opposing each other with the liquid crystal provide therebetween; a plurality of scanning lines; a plurality of data lines; and a switching element and a pixel electrode provided in each of pixel areas defined by the scanning lines and the data lines, wherein a pretilt angle with respect to each of the alignment films is in the range of from 20° to 30°. According to the structure described above, since the display defects caused by disclination are placed outside the pixels, it is not necessary that a black matrix for shading an area at which the disclination is generated be additionally provided, and hence, brighter display can be ensured corresponding to the area described above.

[0014]

In the present invention, the alignment film is preferably composed of one of silicon oxide and silicon nitride. When the alignment film is formed, for example, by an oblique deposition method from the material described above, a pretilt angle of 20° to 30° can be relatively easily realized, and in addition, since the decomposition of the alignment film by light is prevented, the generation of abnormal alignment can be prevented.

[0015]

In addition, in the present invention, when the thickness (cell gap) of a layer of the liquid crystal held between the pair of substrates is represented by d, and when the space between the pixel electrodes is represented by L, $d/L \geq 1$ is preferably held. Disclination is increasingly observable as the cell gap d is decreased

and as the space L between the pixel electrodes is decreased; however, when $d/L \geq 1$ is held as described above, the influence of the lateral electric field is decreased, and in addition, the aperture ratio can be increased.

[0016]

Furthermore, in the present invention, the pixel electrode may be formed from a light-reflecting metal electrode. When the pixel electrode is formed from a light-reflecting metal electrode, switching elements and wires can be formed under the pixel electrodes. Accordingly, the pixel electrodes can be disposed at positions independently of those of the switching elements and the wires.

[0017]

Since a projection type liquid crystal apparatus of the present invention is provided with the liquid crystal device described above, bright display can be performed by preventing the display defects caused by disclination.

[0018]

In particular, when the projection type liquid crystal apparatus comprises a light source, a light modulating device for modulating light emitted from the light source, and a projection lens for projecting the light modulated by the light modulating device, and when the liquid crystal device described above is used as the light modulating device, bright display can be performed by preventing the display defects caused by disclination when images are magnified and projected.

[0019]

Received at: 9:42PM, 2/26/2003

In a manner similar to the above, when the projection type liquid crystal apparatus comprises a light source, a light modulating device for modulating light emitted from the light source, and a projection lens for projecting the light modulated by the light modulating device, and when the liquid crystal device described above is used for a blue display portion as the light modulating device, display can be performed having an improved blue purity.

[0020]

In addition, since an electronic apparatus of the present invention comprises the liquid crystal device described above, bright display can be performed by preventing the display defects caused by disclination.

[0021]

[Description of the Embodiments]

Hereinafter, the embodiments of the present invention will be described with reference to drawings; however, the present invention is not limited to the embodiments described below.

[0022]

<Pixel Portion of a Liquid Crystal Device>

A liquid crystal device of a first embodiment of the present invention will first be described. First, the pixel portion of this liquid crystal device will be described with reference to Figs. 1 and 2. Fig. 1 is a view showing an equivalent circuit of various types of elements and wires of a plurality of pixels arranged in a matrix constituting an image display area of the liquid crystal device. Fig. 2 is an enlarged cross-sectional view of a TFT array substrate showing one

of TFTs in Fig. 1. In this cross-sectional view, in order to allow layers and members to be recognized in the figure, the reduction scales of the individual layers and members are made different from each other.

[0023]

In Fig. 1, in the image display area of the liquid crystal device according to this embodiment, m scanning lines 3a extend in the lateral direction, n data lines 6a extend in the longitudinal direction, and TFTs 30 and pixel electrodes 9a are arranged in a matrix so as to correspond to the cross portions of the scanning lines 3a and the data lines 6a. A gate electrode of the TFT 30 is connected to the scanning line 3a, a source electrode of the TFT 30 is connected to the data line 6a, and a drain electrode is connected to the pixel electrode 9a. In addition, scanning signals G1, G2, ··· Gm, which are sequentially placed at active levels at predetermined timings, are applied to the m scanning lines 3a. Furthermore, in a period of time in which a certain scanning signal is placed at an active level, image signals S1, S2 ··· Sn are supplied in a line sequence manner in this order to the n data lines 6a or are supplied to each group of a plurality of the data lines 6a adjacent to each other.

[0024]

Accordingly, when a certain scanning signal is placed at an active level, all TFTs 30 connected to one scanning line 3a to which said certain scanning signal mentioned above is supplied are simultaneously put in an ON state. In addition, during the period of this ON state, the image signals S1, S2 ··· Sn which are supplied are written in

individual pixel electrodes 9a of said one scanning line described above and are retained for a predetermined time between the pixel electrodes and a counter electrode formed on the counter substrate described below.

[0025]

Since the alignment and regularity of the molecular aggregate of the liquid crystal are changed in accordance with the level of a voltage applied thereto, light passing through the liquid crystal is modulated, and hence, grayscale display can be performed. When liquid crystal is driven in a normally-white mode, incident light is not allowed to pass through the liquid crystal portion in accordance with a voltage applied thereto, and when a normally-black mode is used, incident light is allowed to pass through the liquid crystal portion in accordance with a voltage applied thereto, whereby, on the whole, light having an intensity corresponding to an image signal is emitted from the liquid crystal device. In order to prevent leakage of the retained image signals, a storage capacitance 70 is additionally provided in parallel with a liquid crystal capacitance formed between the pixel electrode 9a and the counter electrode. By this storage capacitance 70, the voltage of the pixel electrode 9a can be held for a time approximately three orders of magnitude longer than the time during which a source voltage is applied, and hence the retention characteristics are improved, whereby a liquid crystal device having a high contrast ratio can be realized.

[0026]

Next, as shown in the enlarged cross-sectional view of Fig. 2,

above the TFT array substrate 10, a pixel switching TFT (switching element) 30 is provided at a location adjacent to the corresponding pixel electrode 9a. In addition, on the pixel electrode 9a, an alignment film 16 is provided at the side opposite to the TFT 30. As described below, the TFT array substrate 10 is adhered to the counter substrate, having the counter electrode and an alignment film formed thereon, with a predetermined gap therebetween, and a liquid crystal layer 50 is formed by filling the liquid crystal in this gap. In addition, when the difference in voltage between the pixel electrode 9a and the counter electrode is not present, the liquid crystal layer 50 is arranged to be placed in a predetermined alignment state because of the alignment films provided at the two substrates.

[0027]

On the TFT array substrate 10, a first shading film 11a is provided at a location opposing the pixel switching TFT 30. The first shading film 11a is preferably composed of a metal element, an alloy, a metal salicide, or the like containing at least one opaque metal having a high melting point selected from Ti, Cr, W, Ta, Mo, and Pd. When being formed from the material mentioned above, the first shading film 11a is not destroyed and is not melted during subsequent treatment at a high temperature. In addition, the first shading film 11a can prevent returned light or the like returned from the TFT array substrate 10 side from entering a channel region 1a' and LDD regions 1b and 1c of the pixel switching TFT 30, and hence the characteristics of the pixel switching TFT 30 can be prevented from being degraded by the generation

of photocurrent.

[0028]

Next, a first interlayer insulating film 12 is provided between the first shading film 11a and a plurality of the pixel switching TFTs 30. The first interlayer insulating film 12 is provided for electrically insulating a semiconductor layer 1a constituting the pixel switching TFT 30 from the first shading film 11a. In addition, since being formed over the entire surface of the TFT array substrate 10, the first interlayer insulating film 12 also serves as an underlying layer for the pixel switching TFT 30. That is, the first interlayer insulating film 12 has the function of preventing the characteristics of the pixel switching TFT 30 from being degraded by a roughened surface of the TFT array substrate 10 caused by polishing, stains remaining thereon after washing, or the like. The first interlayer insulating film 12 is formed, for example, of a high insulation glass, such as NSG (non-doped silicate glass), PSG (phosphorus silicate glass), BSG (boron silicate glass), or BPSG (boron phosphorus silicate glass); a silicon oxide film; or a silicon nitride film. The first interlayer insulating film 12 described above can also prevent the pixel switching TFT 30 or the like from being contaminated by the first shading film 11a. When an opaque Si substrate is used for the TFT array substrate 10, the first shading film 11a is not required.

[0029]

Subsequently, a gate insulating film 2 is formed by thermal oxidation treatment or the like on the surface of the semiconductor

layer 1a constituting the pixel switching TFT 30, and in addition, the scanning line 3a composed of a polycrystalline silicon film is formed. Accordingly, a part of the scanning line 3a crossing the semiconductor layer 1a serves as the gate electrode of the TFT 30, and a part of the semiconductor layer 1a under the scanning line 3a serves as the channel region 1a'. In addition, in parts of the semiconductor layer 1a, which are adjacent to the channel region 1a' at the two sides thereof, a lightly doped source region (LDD region at the source side) 1b and a lightly doped drain region (LDD region at the drain side) 1c are provided, and outside these LDD regions, a highly doped source region 1d and a highly doped drain region 1e are provided, respectively, whereby the TFT 30 has a so-called LDD (lightly doped drain) structure. In the individual regions 1b, 1c, 1d, and 1e are each formed by doping the semiconductor layer 1a with an n-type or a p-type dopant so as to have a predetermined concentration thereof, the dopant being selected in accordance with the formation of an n-type or a p-type channel. Related to this, the n-type channel TFT has an advantage of high processing speed, and hence the n-type channel TFT is used as the pixel switching TFT 30, i.e., a switching element for the pixel, in many cases.

[0030]

In addition, as a material used for the pixel electrode 9a, a transparent conductive film such as ITO (indium tin oxide) is preferably used in a transmissive type, and on the other hand, in a reflective type, a conductive film having high reflectivity, such as Al or Ag, may be used.

[0031]

The highly doped source region 1d of the semiconductor layer 1a constituting the TFT 30 is connected to the data line 6a composed of a shading thin-film containing a metal film having a low resistance, such as Al, or an alloy film, such as a metal silicide, via a contact hole 5 penetrating the gate insulating film 2 and a second interlayer insulating film 4, and on the other hand, the highly doped drain region 1e is connected to the associated pixel electrode 9a via a contact hole 8 penetrating the gate insulating film 2, the second interlayer insulating film 4, and a third interlayer insulating film 7. In addition, the highly doped drain region 1e and the pixel electrode 9a may be electrically connected to each other via the same aluminum film as that for the data line 6a or the same polycrystalline silicon film as that for the scanning line 3a.

[0032]

The TFT 30 preferably has the LDD structure as described above; however, an offset structure may be used in which impurity ion implantation is not performed for the lightly doped source region 1b and the lightly doped drain region 1c, or a self-align type TFT may be used in which impurity ions are implanted at a higher concentration by using the gate electrode 3a as a mask so as to form a highly doped source region and a highly doped drain region in a self-alignment manner.

[0033]

In addition, a highly doped region 1f, adjacent to the highly doped drain region 1e of the semiconductor layer 1a constituting the TFT 30,

extends to a location at which a capacitance line 3b is formed extending approximately parallel to the scanning line 3a, and the highly doped region 1f has a low resistance. Accordingly, the storage capacitance 70 is formed of the highly doped region 1f and a part of the capacitance line 3b with the gate insulating film 2 provided therebetween as a dielectric material. Since the dielectric material of the storage capacitance 70 is the gate insulating film 2 itself which is formed on the polycrystalline silicon film for the TFT 30 by high temperature oxidation, a thin insulating film having a high breakdown voltage can be formed. Consequently, the storage capacitance 70 has a relatively small area and a large capacitance.

[0034]

As a result, by effectively using a space other than that for the aperture area, i.e., the area under the data line 6a and the space along the scanning line 3a, the storage capacitance of the pixel electrode 9a can be increased. In addition, the pixel electrode 9a may be formed above the data line 6a or the scanning line 3a with an insulating film provided therebetween.

[0035]

In this embodiment, a single gate structure is formed in which only one gate electrode (data line 3a) of the pixel switching TFT 30 is provided between the source and the drain regions 1b and 1e; however, at least two gate electrodes may be provided therebetween. In the case described above, the same signal is applied to the individual gate electrodes. When a TFT is formed having a dual gate (double gate) or a

triple gate structure, leakage of current at the junctions of the channel with the source and the drain regions can be prevented, and hence, current in an OFF state can be decreased. When at least one of the gate electrodes described above is formed to have the LDD structure or the offset structure, the Off current can be further decreased, and as a result, a stable switching element can be obtained.

[0036]

Next, in the liquid crystal display device having the structure described above, the relationship among the pretilt angle of the liquid crystal with respect to the alignment film, the space between the pixel electrodes 9a, and the thickness of the liquid crystal layer is investigated. For ease of description, as shown in Fig. 3, a space between body portions 9a1 of the pixel electrodes 9a is represented by L ($\times 10^{-6}$ m), an alignment pitch between the pixel electrodes 9a is represented by P ($\times 10^{-6}$ m), and the thickness (cell gap which is a distance between the alignment film 16 at the substrate 10 side and an alignment film 22 at a substrate 20 side) of the liquid crystal layer is represented by d ($\times 10^{-6}$ m). In addition, an angle (pretilt angle) formed by the long axis of the liquid crystal molecule and the surface of the substrate (alignment film) is represented by θp.

[0037]

In the structure shown in Figs. 1 and 2, the alignment pitch P was set 25 $\times 10^{-6}$ m, and the size of the pixel electrode 9a was set to 15 $\times 10^{-6}$ square (accordingly, the space L was 10 $\times 10^{-6}$ m). In addition, the cell gap d was set to 5 $\times 10^{-6}$ m. Furthermore, the alignment films

Received at: 9:42PM, 2/26/2003

16 and 22 were formed from SiO_2, which is an inorganic material, the pretilt angle θp was set to 25° by an oblique deposition method, and a twist nematic alignment mode having an angle of 45° between the two substrates was formed. In the case described above, the product Δn·d of the refractive anisotropy Δn of a negative type nematic liquid crystal and the cell gap d was set to 0.48×10^{-6} m.

[0038]

In addition, although not shown in the figure, the counter substrate 20 was provided with micro lenses composed of a photosensitive resin, acrylic adhesive covering the micro lenses, and cover glasses at the rear surface (upper side) of the substrate.

[0039]

Under the conditions described above, while the influence of lateral electric fields from the adjacent pixel electrodes was taken into consideration, the state of liquid crystal alignment was computed for simulating the lightness at the pixel electrode in relation to the light reflectance. The results are shown in Fig. 8. In this figure, compared to the conventional example shown in Fig. 14, it is understood that display defects, which are caused by disclination, are clearly decreased.

[0040]

Subsequently, in the case in which the pretilt angle θp was changed while the Δn·d is fixed to 0.48 μm, necessary cell gaps d were computed. The results are shown in the table below (Table 1). In this Table, the reflectance obtained when the dot inversion driving method was employed

as a driving method and the response speeds thereof obtained by computing are also shown in this Table.

[0041]

[Table 1]

Pretilt Angle (degree)	0	5	10	20	30	40	50
Δn	0.15	0.148	0.145	0.13	0.108	0.08	0.057
Cell Thickness	3.2	3.24	3.31	3.7	4.4	6	8.4
Reflectance (%)	42	44	45	56	60	62	63
Response Time (ms)	46	47	50	62.7	72	165	324

[0042]

As can be seen in Table 1, it is understood that the cell gap d is increased when the pretilt angle θp is 30° or more. In addition, since it has been known that the response time is increased in proportion to the square of the cell gap d, the trend is not preferable in which the cell gap d is increased. Furthermore, the reflectance is decreased when the pretilt angle θp is 20° or less, and the reason for this is that disclination occurs. Accordingly, it is considered that the pretilt angle θp is preferably set in the range of from 20° to 30°.

[0043]

As described above, since being increased as the cell gap d is decreased and as the space L between the pixel electrodes is deceased,

the influence of the lateral electric field can be apparently observed in a highly fine panel. In addition, as described with reference to Table 1, the response time is increased as the cell gap d is increased, and concerning the lightness, when the cell gap d is decreased in the case in which the Δn·d is maintained constant, a liquid crystal material having a high Δn is required. However, since the number of reliable liquid crystal materials having a high Δn is very small, the use of the liquid crystal mentioned above is disadvantageous from the process point of view.

[0044]

Next, in the case in which the alignment pitch P of the pixel electrodes 9a was set to 10 μm, and the cell gap d was maintained at a constant value of 3.2 μm, the change in aperture ratio with the change in space L between the pixel electrodes was measured. The results are shown in the table below (Table 2).

[0045]

[Table 2]

L (μm)	1	2	3	4
d (μm)	3.2	3.2	3.2	3.2
d/L	3.2	1.6	1.06	0.8
Aperture Ratio (%)	90	80	70	60

[0046]

In this embodiment, the pretilt angle θp is set ~~in the range of~~ from 20° to 30°. In order to decrease the influence of the lateral electric field, increase the aperture ratio, and obtain high contrast, d/L ≥ 1 must be held between the cell gap d and the space L. In the case of a normally white display mode, although the space between the pixel electrodes is decreased so as to have a high aperture ratio, light leakage occurs in black display by the generation of lateral electric fields. Due to the light leakage, even though the aperture ratio is high, bright display having a high contrast cannot be obtained. The contrast ratio of the liquid crystal display device for a current projection type apparatus is required to be 200 or more. In order to fulfill this requirement, the conditions described above are necessary.

[0047]

Accordingly, when the pretilt angle θp is set in the range of from 20° to 30°, and in addition, when the cell gap d and the space L are set such that d/L ≥ 1 is held, the probability of the generation of disclination lines is decreased in the pixel even when there is the influence of the lateral electric fields by other pixel electrodes adjacent thereto. As a result, even in a highly fine display structure, display having high quality and a high contrast ratio can be performed.

[0048]

<Entire Structure of Liquid Crystal Device>

Next, the entire structure of the liquid crystal device according to this embodiment will be described with reference to Figs. 4 and 5. In Fig. 4, on the TFT array substrate 10 and along the periphery thereof,

a sealing material 52 is provided, and in parallel to the inside thereof, a shading film 53 is provided as a peripheral delimiter. In an area outside the sealing material 52, a data line driving circuit 101 and a mounting terminal 102 are provided along one side of the TFT array substrate 10, and along two sides thereof adjacent to said one side mentioned above, scanning line driving circuits 104 are provided. When delay of scanning signals supplied to the scanning lines 3a does not cause a problem, the scanning line driving circuit 104 is naturally provided along one of the two side described above. In addition, the data line driving circuits 101 may be provided along two sides of the image display area. Furthermore, along the remaining side of the TFT array substrate 10, a plurality of wires 105 is provided for connecting between the scanning line driving circuits 104 provided along the two sides of the image display area. As shown in Fig. 5, the counter substrate 20 having an outline approximately equivalent to that of the sealing material 52 is tightly bonded to the TFT array substrate 10 with the sealing material 52 so as to have a predetermined gap d therebetween, and in addition, liquid crystal is enclosed in the space thus formed, whereby the liquid crystal layer 50 is formed. The sealing material 52 is an adhesive composed, for example, of a photocurable resin or a thermosetting resin, and spacers (not shown in the figure) in the form of a bar or a sphere are added to and mixed with this sealing material 52 so that the predetermined gap d can be maintained.

[0049]

In addition, at one side of the counter substrate 20 on which

projection light is incident and at one side of the TFT array substrate 10 from which light is emitted, a polarizing film, retardation film, polarizer, or the like are optionally provided in predetermined directions, for example, in accordance with an operation mode, such as a TN (twisted nematic) mode, an STN (super TN) mode, or a ferroelectric liquid crystal (FLC) mode; or a normally-white mode or a normally-black mode.

[0050]

Since the liquid crystal device of the embodiment described above is applied to a color liquid crystal projector, three liquid crystal devices are used as light valves for RGB colors, and in addition, as described below, light having each color separated by a dichroic mirror for RGB color separation is incident on each of the liquid crystal device as projection light.

[0051]

Accordingly, in this embodiment, color filters are not provided at the counter substrate 20 side. However, on the counter substrate 20, color filters for RGB may be provided with a protective film at areas opposing the pixel electrodes 9a. According to the structure described above, in addition to the liquid crystal projectors, the liquid crystal devices of the embodiments may be applied to color liquid crystal apparatuses, such as a direct-view-type or a reflective type color liquid crystal television. In addition, by depositing a plurality of interference films having different refractive indexes from each other on the counter substrate 20, a dichroic filter may be formed which

produces RGB colors using the light interference. By the counter substrate provided with this dichroic filter, a brighter color liquid crystal apparatus can be realized.

[0052]

In addition, as the switching element provided in each pixel, the normal stagger type or the coplanar type TFT composed of polycrystalline silicon was descried; however, other TFTs, such as an inverted stagger TFT, or a TFT composed of amorphous silicon, may be effectively used in the embodiment.

[0053]

In this embodiment, the structure is formed in which the pixel electrode 9a is driven by using a TFT; however, in addition to the TFT, an active matrix element such as a TFD (thin-film diode) may also be used. In addition, the liquid crystal device may be formed as a passive matrix liquid crystal device.

[0054]

Fig. 6 is a view for illustrating driving methods applicable to the liquid crystal device of this embodiment for driving. First, when each rectangular area defined by lines as shown in Fig. 6(a) is assumed to be one pixel, a method for applying voltages having the same polarity to all pixels enclosed by a frame may be employed, in other words, a frame inversion driving method for repeatedly applying voltages to individual frames may be employed in which a positive potential is applied to every pixel enclosed by the frame shown in Fig. 6(a) and a negative potential is applied to every pixel enclosed by the other frame which is not shown.

Secondary, as shown in Fig. 6(b), a dot inversion driving method may be employed in which voltages having different polarities are applied to individual pixels adjacent to each other in the longitudinal and lateral directions. Thirdly, as shown in Fig. 6(c), a method for applying voltages having different polarities to lines adjacent to each other in the lateral direction or, as shown in Fig. 6(d), a method for applying voltages having different polarities to lines adjacent to each other in the longitudinal direction may be employed.

[0055]

In a conventional highly fine liquid crystal device having the structure in which spaces between pixel electrodes are decreased to approximately 1×10^{-6} m, the frame inversion driving method is the only method to be employed because of the influence of the lateral electric field. The reason for this is that when the dot inversion driving or the frame inversion driving is performed, display defects may occur in some cases due to the generation of disclination lines. In contrast, when the structure of this embodiment is employed, even when a driving method is employed in which voltages having different polarities are applied to the pixels adjacent to each other, the probability of the generation of disclination lines in the display area is decreased. As a result, even when the dot inversion driving method shown in Fig. 6(b) or the line inversion driving method shown in Figs. 6(c) or 6(d) is employed, the generation of the disclination can be suppressed. Accordingly, in this embodiment, since any of the driving methods can be used for the liquid crystal device, the applications thereof can be more

increased.

[0056]

[Second Embodiment]

Next, a liquid crystal device of a second embodiment of the present invention will be described. In this liquid crystal device, the TFT array substrate 10 of the first embodiment is composed of a semiconductor substrate, and pixel-switching active elements are formed in the semiconductor substrate. In the case described above, since the semiconductor substrate has no light-transmitting characteristics, the liquid crystal device is used as a reflective type device.

[0057]

Fig. 7 is a cross-sectional view showing the structure of one pixel-switching field-effect transistor in the reflective liquid crystal device according to this embodiment. The equivalent circuit of this liquid crystal device has not any different point from that shown in the first embodiment.

[0058]

In the figure, reference numeral 101 indicates a p-type or an n-type semiconductor substrate such as single crystalline silicon, and reference numeral 102 indicates a p-type or an n-type well region which has an impurity concentration higher than that of the semiconductor substrate 101 and which is formed in the surface thereof. The well region 102 is not specifically limited; however, in the case of a highly fine liquid crystal panel having pixels, for example, composed of not less than 768 in the longitudinal line by 1,024 in the lateral line, the

well regions of these pixels are formed as a common well region, and in some cases, the common well region may be formed separately from well regions in which other elements are formed constituting peripheral circuits, such as a data line driving circuit, scanning line driving circuits, an input-output circuit, a timing circuit, and the like.

[0059]

Next, reference numeral 103 indicates a field oxide film (so-called LOCOS) for element isolation formed on the surface of the semiconductor substrate 101. The field oxide film 103 is formed, for example, by selective thermal oxidation. An opening is formed in the field oxide film 103, and a gate electrode 105a and a scanning line composed of polycrystalline silicon, a metal silicide, or the like is formed at a central portion inside the opening mentioned above and on a gate oxide film 114 formed by thermal oxidation of the surface of the silicon substrate. In addition, a source region 106a and a drain region 106b, each composed of a n-type impurity layer (doped layer) having an impurity concentration higher than that of the well region 102, are formed at the substrate surface side and at two sides of the gate electrode 105a, whereby a field effect transistor (FET, switching element) 105 is formed.

[0060]

Above the source region 106a and the drain region 106b, first conductive layers 107a and 107b composed of a first aluminum layer are formed with a first interlayer insulating film 104 composed of a BPSG (boron phosphorus silicate glass) film or the like provided therebetween.

The first conductive layer 107a is electrically connected to the source region 106a via a contact hole formed in the first interlayer insulating film 104 to form a source electrode (corresponding to the data line) for supplying a voltage of the data signal to the source region 106a. In addition, the first conductive layer 107b forms a drain electrode in the first interlayer insulating film 104.

[0061]

Next, a second interlayer insulating film 108 composed of silicon dioxide or the like is formed on the first conductive layers 107a and 107b, and in addition, a second conductive layer 109 composed of an aluminum layer or a tantalum layer is formed on the second interlayer insulating film 108.

[0062]

Furthermore, on the second conductive layer 109, an insulating layer 110 is formed from a material having a high dielectric constant, such as silicon dioxide, silicon nitride, or tantalum oxide, and a pixel electrode 112, which is composed of a light-reflecting metal and which is connected to the drain electrode 107b, is formed on the insulating layer 110. The pixel electrode 112 described above and the second conductive layer 109 are formed with the insulating layer 110 provided therebetween. As a result, holding capacitances 113 are formed. Accordingly, the second conductive layer 109 preferably has a planarized surface. In the structure described above, a wire is electrically connected to the second conductive layer 109 for applying one predetermined potential selected among a common potential electrode Vcom

of the liquid crystal panel or a potential in the vicinity thereof; a center potential of the amplitude of a voltage (data signal voltage) applied to the pixel electrode (reflective electrode) 112 or a potential in the vicinity thereof; and an intermediate potential between the common electrode potential and the center potential of the voltage amplitude described above. The common electrode potential Vcom corresponds to an inversion central potential when polarity inversion drive of the liquid crystal layer is performed.

[0063]

The pixel electrodes 12 shown in Fig. 7 are arranged in a matrix in plan view as in the case in the first embodiment, an alignment film not shown in the figure is formed on these pixel electrodes 112, a counter substrate equivalent to that in the first embodiment is disposed at a side opposing the semiconductor substrate 101, and in addition, a liquid crystal layer is held between the substrates, whereby a reflective type liquid crystal display device is formed.

[0064]

In the semiconductor substrate 101 of the liquid crystal display device according to this second embodiment, as is the structure of the previous embodiment described above, when the pretilt angle θp is set in the range of from 20° to 30°C, and in addition, when the relationship between the cell gap d and the space L is set so that d/L ≥ 1 is held, the probability of the generation of disclination lines is decreased in the pixel even when influence of the lateral electric fields, which are caused by other pixels adjacent thereto, is given to the pixel. As a

result, even though a highly fine structure is formed, display having high quality and a high contrast ratio can be performed.

[0065]

<Projector>

Next, several applications using the liquid crystal devices of the embodiments described above will be described. First, a projection type display apparatus (liquid crystal projector), which uses the liquid crystal devices as light valves, will be described. Fig. 9 is a view showing the structure of the liquid crystal projector.

[0066]

The liquid crystal projector comprises a polarizing illumination device 700 primarily composed of a light source portion 710 provided along a system optical axis L, an integrator lens 720, and a polarization converter 730: a polarized light beam splitter 740 having a s-polarized light flux reflection surface 741 for reflecting s-polarized light fluxes emitted from the polarizing illumination device 700; a dichroic mirror 742 separating a blue light (B) component from light reflected from the s-polarized light flux reflection surface 741 of the polarized light beam splitter 740; a reflective liquid crystal light valve 745B modulating the separated blue light (B); a dichroic mirror 743 separating a red light (R) component by reflecting light fluxes obtained after the blue light component is separated; a reflective liquid crystal light valve 745R modulating the separated red light (R); a reflective liquid crystal light valve 745G modulating remaining green light (G) passing through the dichroic mirror 743; and a projection

optical system 750 which synthesize the light modulated by the three reflective liquid crystal light valves 745R, 745G, and 745B using the dichroic mirrors 743 and 742 and the polarized light beam splitter 740, and which projects this synthesized light on a screen 760. In this structure, the reflective liquid crystal display devices (liquid crystal panels) according to the embodiment are used for the three reflective liquid crystal light valves 745R, 745G, and 745B.

[0067]

In the structure described above, after random polarized light fluxes emitted from the light source portion 710 are separated into a plurality of intermediate light fluxes by the integrator lens 720, the intermediate light fluxes are converted into one type of polarized light fluxes (s-polarized light fluxes), in which the polarized directions are substantially identical, by the polarization converter 720 having a second integrator lens at a light incident side thereof, and this polarized light fluxes then reach the polarized light beam splitter 740. The s-polarized light fluxes emitted from the polarization converter 730 are reflected from the s-polarized light flux reflection surface 741 of the polarized light beam splitter 740, and of the reflected light fluxes, a blue (B) light flux is reflected from a blue light reflection layer of the dichroic mirror 742 and is then modulated by the reflective liquid crystal light valve 745B. Of the light fluxes passing through the blue light reflection layer of the dichroic mirror 742, a red (R) light flux is reflected from a red light reflection layer of the dichroic mirror 743 and is then modulated by the reflective liquid crystal light valve

745R. In addition, a green (G) light flux passing through the red light reflection layer is modulated by the reflective liquid crystal light valve 745G. As described above, light colors are modulated by the reflective liquid crystal light valves 745R, 745G, and 745B.

[0068]

The s-polarized light component of the light colors reflected from the pixels of the liquid crystal panel is not allowed to pass through the polarized light beam splitter 740 reflecting the s-polarized light, but a p-polarized light component is allowed to pass therethrough. The light transmitted through the polarized light beam splitter 740 forms an image. Accordingly, in the case in which a TN type liquid crystal is used for a liquid crystal panel, reflected light from an OFF pixel reaches the projection optical system 750, and reflected light from an ON pixel does not reach a lens, whereby a projection image is normally white display.

[0069]

In addition, when the liquid crystal display device of the embodiment is specifically used for the blue light valve 745B, and the cut-off wavelength of blue light is set to 400 nm, display having improved color purity can be performed.

[0070]

Compared to a type having TFT arrays formed on a glass substrate, in the reflective liquid crystal panel, since the pixels are formed by using semiconductor techniques, a larger number of pixels can be formed, and the panel size can also be reduced, highly fine images can be

projected, and in addition, the projector itself can be miniaturized.

[0071]

[Electronic Apparatus]

Next, particular examples of electronic apparatuses each provided with one of the liquid crystal display devices of the embodiments will be described. Fig. 10(a) is a perspective view showing an example of a mobile phone. In Fig. 10(a), reference numeral 1000 indicates a mobile phone body, and reference numeral 1001 indicates a liquid crystal display portion using the liquid crystal display device of the embodiment.

[0072]

Fig. 10(b) is a perspective view showing an example of a wristwatch type electronic apparatus. In Fig. 10(b), reference numeral 1100 indicates a watch body, and reference numeral 1101 indicates a liquid crystal display portion using one of the liquid crystal display devices of the embodiments.

[0073]

Fig. 10(c) is a perspective view showing an example of a portable information processing apparatus, such as a word processor or a personal computer. In Fig. 10(c), reference numeral 1200 indicates an information processing apparatus, reference numeral 1202 indicates an input portion, such as a keyboard, reference numeral 1204 indicates an information processing body, and reference numeral 1206 indicates a liquid crystal display portion using the liquid crystal display device of the embodiment.

[0074]

Since these electronic apparatuses described above are each provided with the liquid crystal display device of the first or the second embodiment, highly fine display having a high contrast ratio can be performed.

[0075]

[Advantages]

As has thus been described, according to the present invention, bright display can be performed by suppressing the generation of the display defects caused by abnormal alignment of the liquid crystal.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a view of an equivalent circuit showing the structure of a display area of a TFT substrate of a liquid crystal device according to a first embodiment of the present invention.

[Fig. 2]

Fig. 2 is an enlarged cross-sectional view showing the structure of one TFT of the TFT array substrate.

[Fig. 3]

Fig. 3 is a schematic view for illustrating the relationship among a pixel pitch, a space between pixel electrodes, and the thickness of a liquid crystal layer in the liquid crystal device.

[Fig. 4]

Fig. 4 is a view showing the entire structure of the liquid crystal device.

Received at: 9:42PM, 2/26/2003

[Fig. 5]

Fig. 5 is a cross-sectional view taken along the line H-H' in Fig. 4.

[Fig. 6]

Figs. 6(a) to (d) are views showing voltage distributions in individual pixels of driving methods applicable to the liquid crystal device.

[Fig. 7]

Fig. 7 is a cross-sectional view showing the structure in which a Si substrate is used as a substrate of the liquid crystal device.

[Fig. 8]

Fig. 8 is a view showing the lightness obtained by computing a light reflection state in the liquid crystal device.

[Fig. 9]

Fig. 9 is a view showing the structure of a liquid crystal projector provided with a liquid crystal device of one embodiment according to the present invention.

[Fig. 10]

Fig. 10(a) is a perspective view of a mobile phone, Fig. 10(b) is a perspective view of a wristwatch, and Fig. 10(c) is a perspective view of a portable information processing apparatus.

[Fig. 11]

Fig. 11 is a view showing the positional relationship among pixel electrodes provided at an elemental substrate side and a common electrode provided at a counter substrate side of a conventional liquid

crystal device.

[Fig. 12]

Fig. 12 is a view showing the state in which disclination is generated in liquid crystal alignment by the influence of a lateral electric field in a conventional liquid crystal device.

[Fig. 13]

Fig. 13 is a view showing the state in which a letter "A" is displayed in black on a white display background in a conventional liquid crystal device.

[Fig. 14]

Fig. 14 is a view showing the lightness obtained by computing light reflection in the state in which disclination is generated in liquid crystal alignment by the influence of a lateral electric field in a conventional liquid crystal device.

[Reference Numerals]

8 ··· contact hole

9a ··· pixel electrode

10 ··· substrate

16 ··· insulating layer

20 ··· second substrate

30 ··· TFT

50 ··· liquid crystal layer

101 ··· semiconductor substrate

105 ··· field effect transistor

112 ··· pixel electrode

700 ··· projection type display apparatus

1000 ··· mobile phone

1100 ··· wristwatch

1200 ··· information processing apparatus

[Name of Document] ABSTRACT

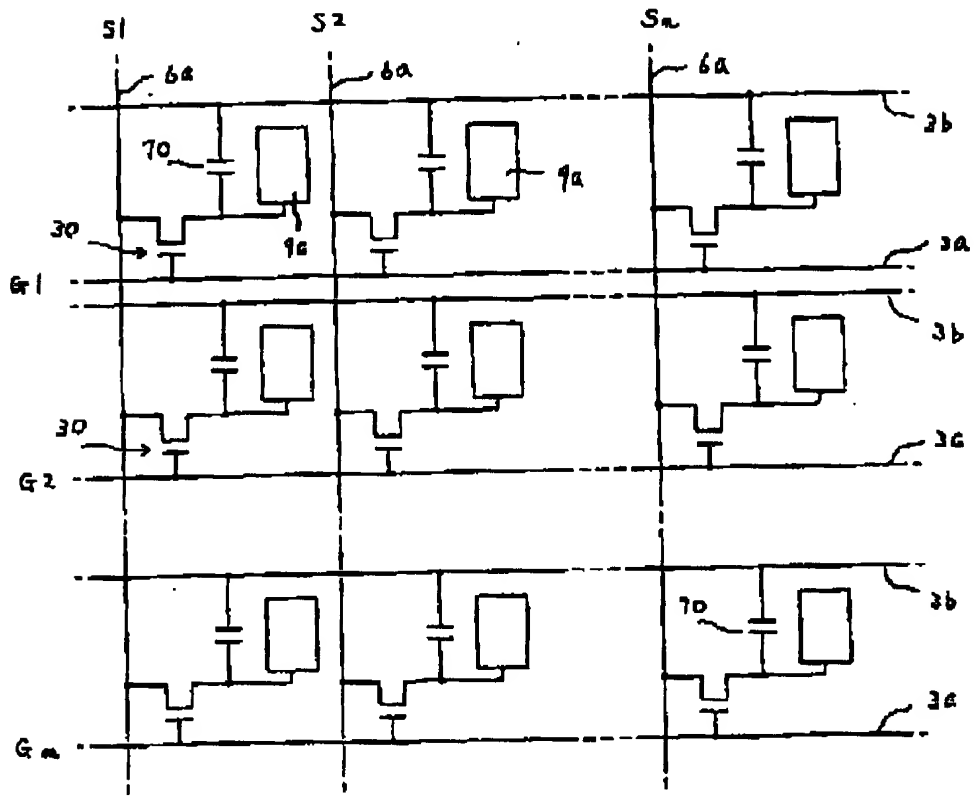
[ABSTRACT]

[Object] An object of the present invention is to provide a liquid crystal device and a projection type display apparatus, having capability of performing high contrast display by suppressing the generation of display defects caused by disclination in a highly fine projection type liquid crystal panel.

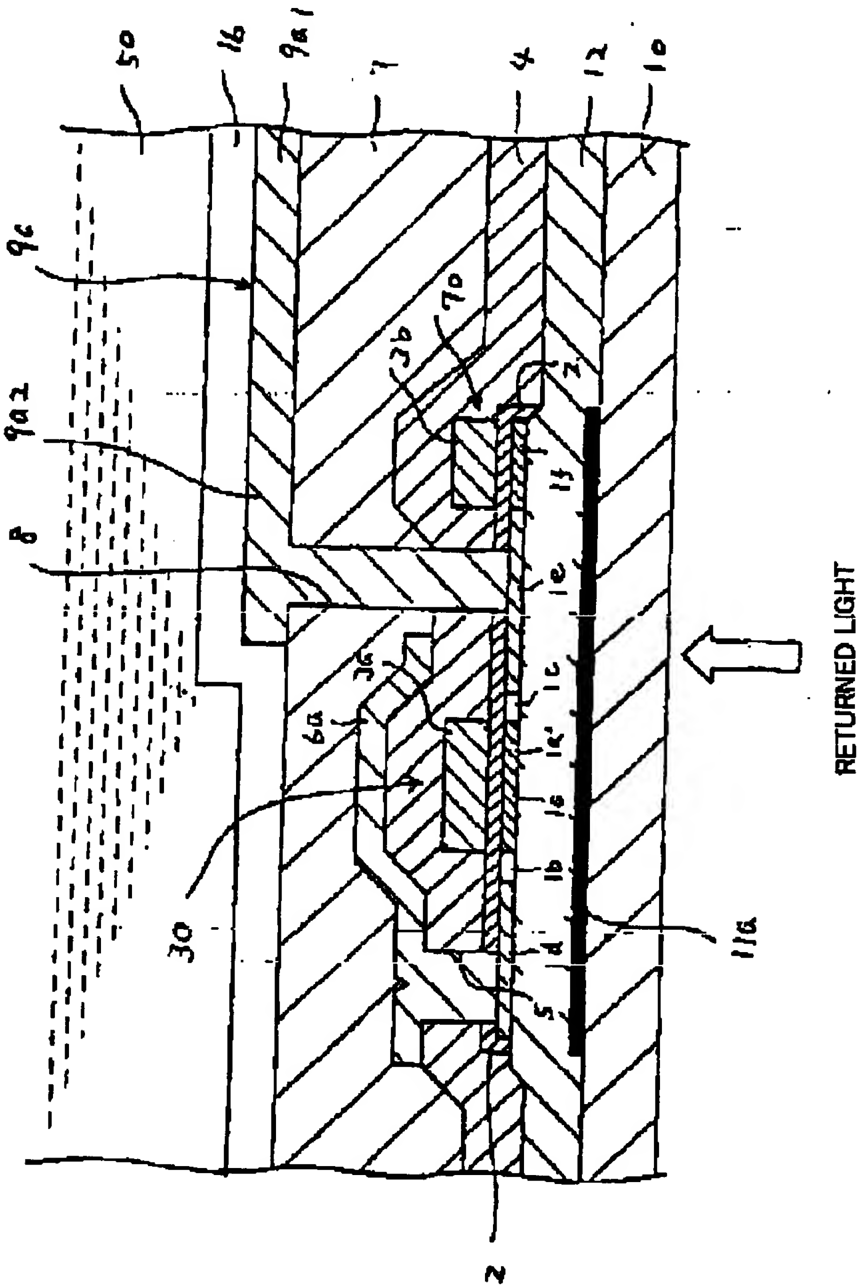
[Solving Means] According to the present invention, a liquid crystal layer 50 is held between one substrate 10 and the other substrate 20, and on the substrate 10, pixel electrodes 9a disposed in a matrix and TFTs 30 driving the respective pixel electrodes are provided. In the structure described above, when the thickness of the liquid crystal between the substrates is represented by d, and when the alignment angle (pretilt angle) of the liquid crystal with respect to the substrate is represented by θp, $20° \leq \theta p \leq 30°$ and $1 \leq d/L$ are satisfied.

[Selected Figure] Fig. 3

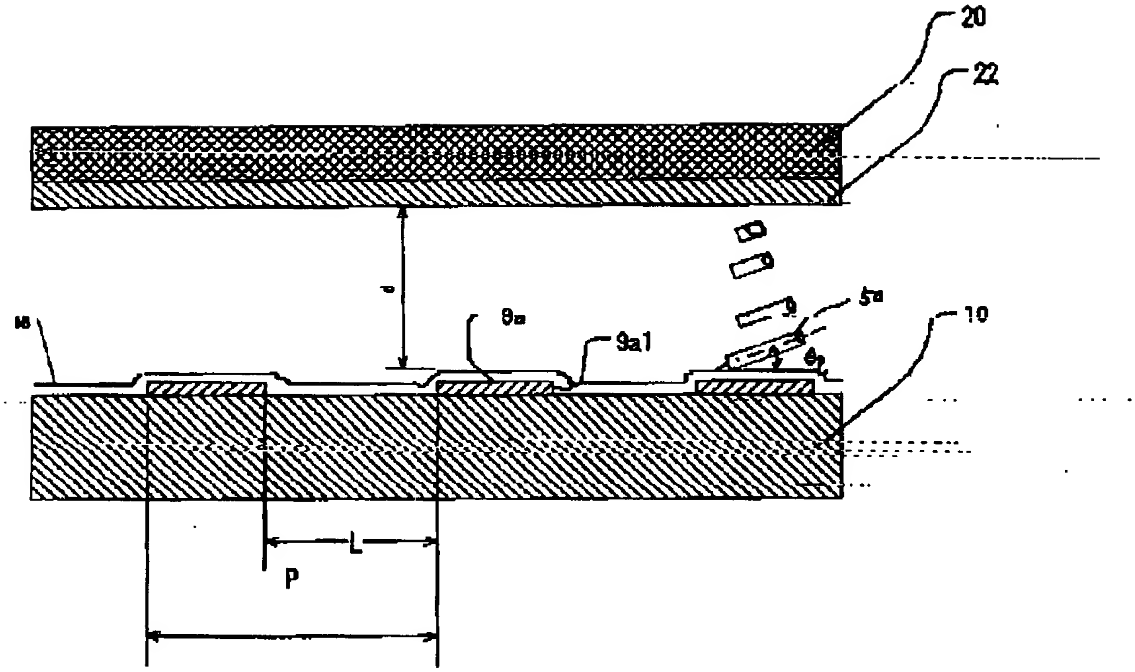
【FIG. 1】



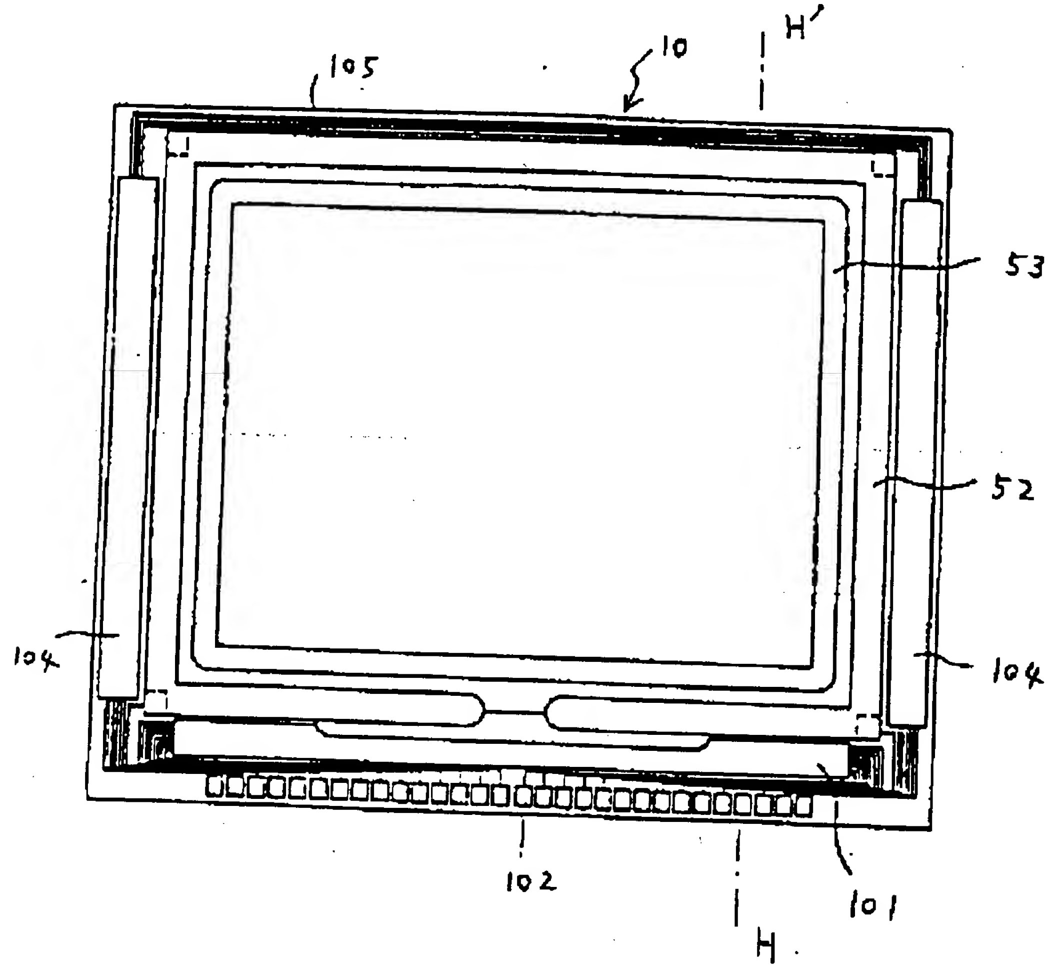
【FIG. 2】



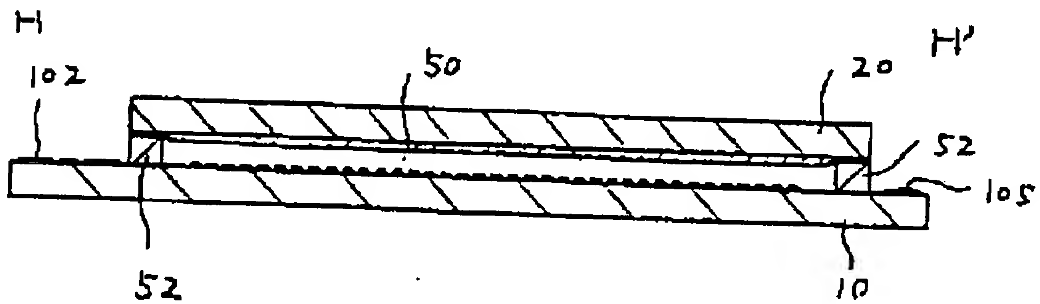
【FIG. 3】



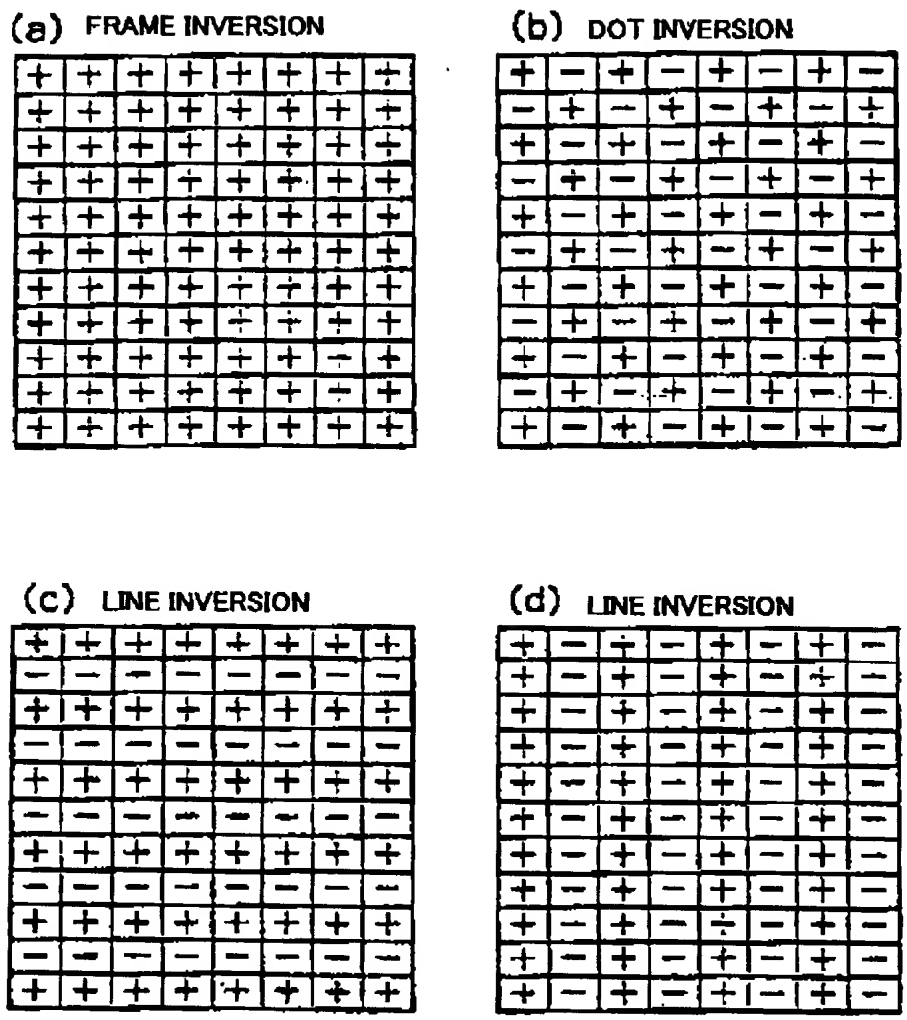
【FIG. 4】



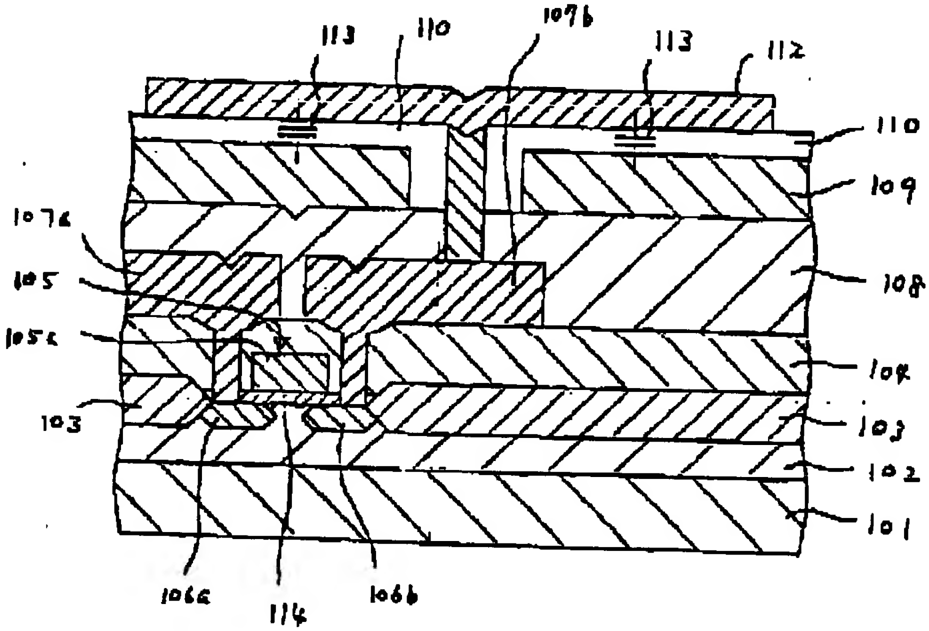
【FIG. 5】



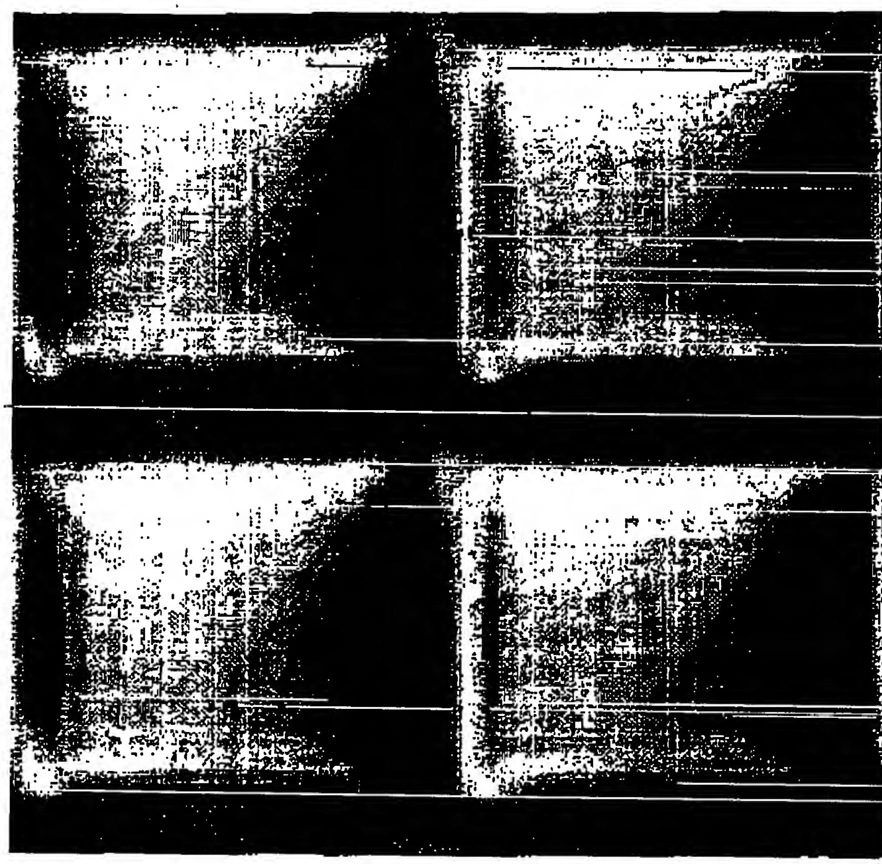
【FIG. 6】


(a) FRAME INVERSION
(b) DOT INVERSION
(c) LINE INVERSION
(d) LINE INVERSION

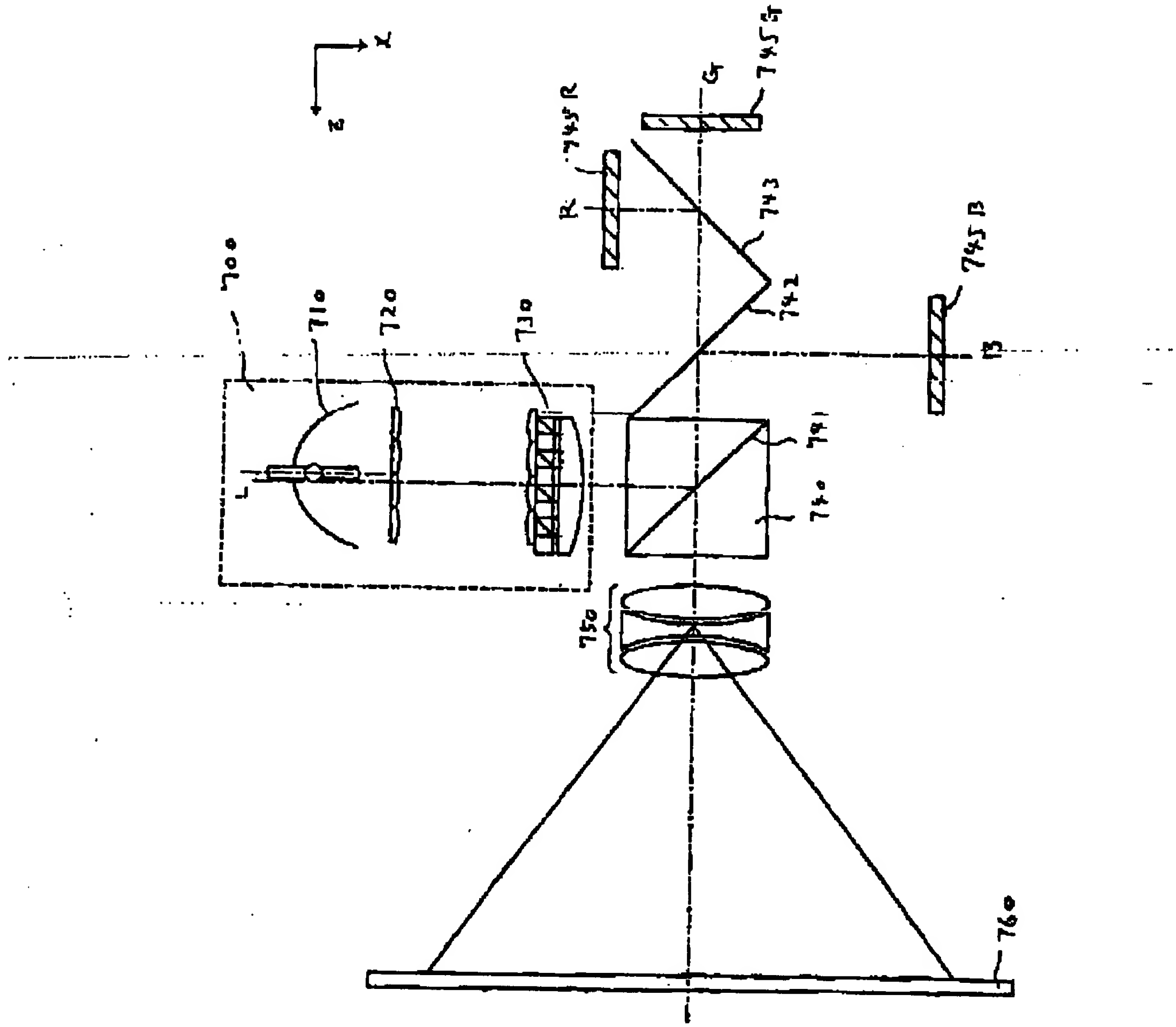
【FIG. 7】


113
110
107b
113
112
110
109
107a
105
105a
108
104
103
103
102
101
106a
114
106b

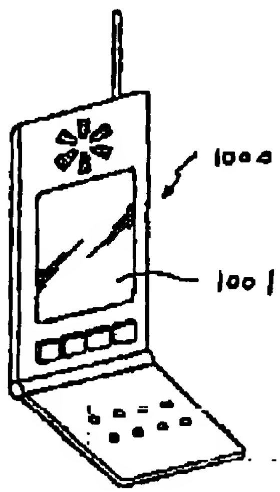
【FIG. 8】

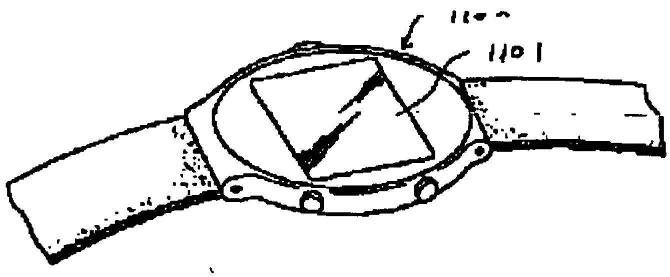


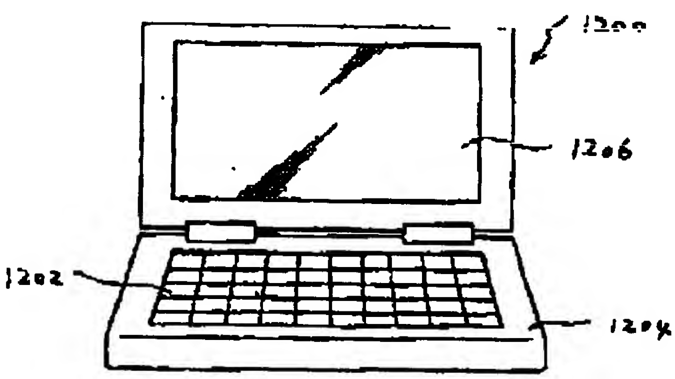
【FIG. 9】



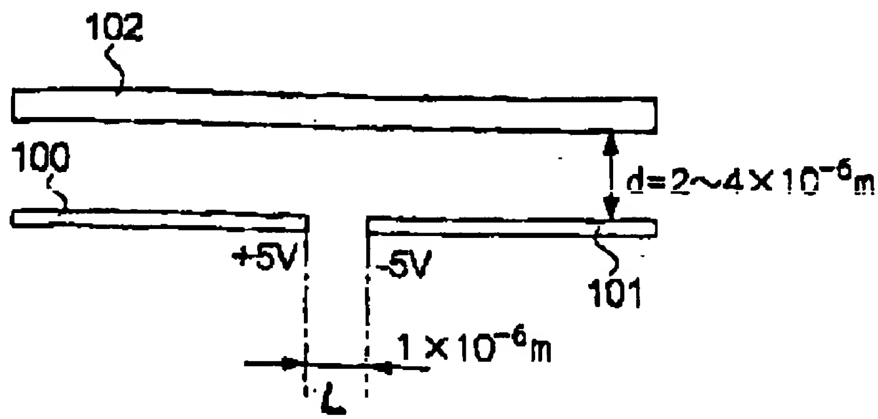
【FIG. 10】



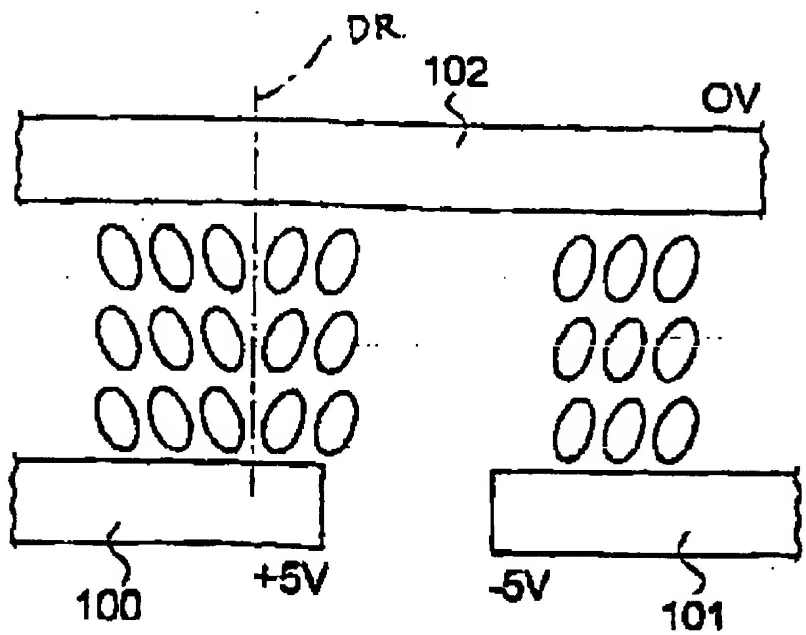




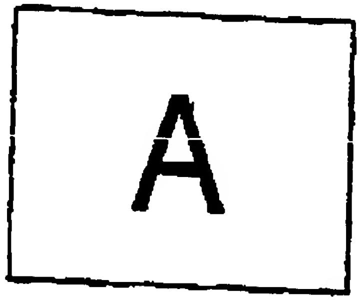
【FIG. 11】



【FIG. 12】



【FIG. 13】



【FIG. 14】